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REVIEW

Contemporary Management of Aorto-iliac Aneurysms in the Endovascular Era

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Abstract Up to 40% of abdominal aortic aneurysms have co-existing unilateral or bilateral iliac artery ectasia or aneurysm. These are associated with an increased risk of endoleak, morbidity and mortality following endoluminal repair. To reduce the adverse sequelae of internal iliac artery (IIA) occlusion, various open, endovascular and hybrid measures have been described to maintain perfusion to the pelvis. This review discusses the contemporary management of aorto-iliac aneurysm in the endovascular era with reference to the sequelae of IIA occlusion and the strategies to preserve IIA perfusion. Particular consideration is given to iliac bifurcation devices.

Introduction

The 17 years that have followed Parodi's pioneering endoaneurysmorraphy have witnessed numerous refinements in endograft technology. The development of modular stent graft systems has afforded the versatility to treat a broader array of abdominal aortic aneurysm (AAA) morphologies.[1] The general applicability of endovascular aneurysm repair (EVAR) continues to be constrained by hostile anatomy,[2] difficult access[3] and aneurysmal extension into the iliac arteries.

Although isolated iliac aneurysms are uncommon with a prevalence of 0.008—0.03%,[4] up to 40% of AAA have co-existing unilateral or bilateral iliac artery ectasia or aneurysm.[5,6] Aorto-iliac aneurysm poses particular challenges to the vascular specialist when compared to isolated aortic aneurysm. The EUROSTAR experience has shown concomitant aortic and iliac aneurysms to be associated with an increased prevalence of cardiac, renal and respiratory comorbidity, in addition to more complex anatomy.[6] Furthermore, EVAR of aorto-iliac aneurysms using conventional endografts was found to be associated with a greater incidence of type I endoleak, secondary interventions and delayed rupture.

Internal iliac artery (IIA) embolisation or coverage due to absence of a suitable common iliac artery landing zone is now a common necessity. For example, in a large single-centre

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experience, intentional IIA occlusion was required in 26% of all aortic endografts (24% unilateral and 2% bilateral).[7] It has become well recognised that unilateral and bilateral IIA occlusions are associated with variable risks of complications, including: buttock or thigh claudication, sexual dysfunction, colonic ischaemia, perineal necrosis, non-healing pressure sores, paraesthesia and incontinence and acute limb ischaemia.[8,9] Notable factors that promote pelvic ischaemic complications following IIA occlusion include greater than 70% stenosis at the origin of the contralateral IIA, absence of filling of three or more named IIA branches, and diseased or absent ascending branches from the ipsilateral common femoral artery.[7]

To reduce the adverse sequelae of IIA occlusion, various open, endovascular and hybrid measures have been described to maintain perfusion to the pelvis. This article reviews the contemporary management of aorto-iliac aneurysm in the endovascular era. A review of the sequelae of unilateral and bilateral IIA occlusions is presented. The hybrid and endovascular stratagems for IIA preservation are then discussed with special consideration given to iliac bifurcation devices (IBDs).

Sequelae of Unilateral and Bilateral Internal Iliac Artery Occlusions

An assertion held by many vascular specialists is that unilateral IIA occlusion carries a lower incidence of ischaemic complications than bilateral. Over a dozen studies have contrasted the sequelae of unilateral and bilateral IIA occlusions in reference to buttock/thigh claudication and erectile dysfunction. These data have been reviewed by Rayt et al. who compared 29 patients who had undergone either unilateral or bilateral IIA occlusions with the published literature.[10] The authors found no significant differences in claudication rates following unilateral and bilateral IIA occlusion. In 11 papers detailing follow up of 301 patients undergoing unilateral IIA occlusion, 29% developed buttock claudication and 18% sexual dysfunction. In comparison, eight series following up a total of 90 patients after bilateral IIA occlusion found incidences of post-procedural buttock claudication and sexual dysfunction to be 32% and 18%. No statistically significant difference was shown between unilateral and bilateral IIA occlusions. Similarly, a series of 39 patients undergoing bilateral IIA embolisation prior to EVAR found post-procedural buttock claudication in 31% of patients, falling to 9% after one year. Sexual dysfunction was only seen in 5% and spinal ischaemia in 3%.[11] There did not appear to be any clinical advantage in performing sequential over simultaneous IIA embolisation with a view to promote collateral vessel development.

Interpretation of these data is constrained by small numbers within most individual series, subjectivity in patient assessment and heterogeneity in follow up. Also, the aetiology and assessment of sexual dysfunction may be difficult given the common confounding co-morbidities of diabetes mellitus, prostate surgery, renal failure and advanced age. Nevertheless, the published evidence is counter to the commonly held belief that more adverse outcomes may be expected with bilateral IIA sacrifice.

Sequelae of Internal Iliac Artery Non-Embolisation

Evidence is now emerging that challenges the traditional paradigm of IIA embolisation prior to EVAR for aorto-iliac aneurysm. A retrospective analysis of 11 EVARs that had been preceded by unsuccessful IIA embolisation found no endoleaks.[12] It is hypothesized that the complex iliac anatomy precluding IIA intubation in these patients protects against back bleeding into the aneurysm sac. These data harmonise with other small series where IIA embolisation was not performed and the ostium covered either by a bridging stent through which the EVAR endograft is deployed,[13] or by the stent graft itself.[14] Though it would be precipitate to conclude that IIA embolisation is unnecessary, inaccessibility of the IIA should not be viewed as an absolute contraindication to aorto-iliac EVAR.

The question of whether IIA coverage or coil embolisation results in worse pelvic ischaemia or increased endoleak was addressed in a single-centre experience of 147 patients requiring occlusion of one or both IIA (67 coil embolisations, 80 coverage by stent graft limb).[15] At six months there was a significantly higher incidence of buttock ischaemia following embolisation compared to IIA ostium coverage (42% Versus 8%). Incidence of sexual dysfunction and endoleak was however unchanged. Similar findings were found by Wyers et al., who demonstrated buttock claudication in 27% of patients undergoing IIA coverage versus 45% of those undergoing embolisation.[14] Left ventricular dysfunction and young age were found particular risk factors for buttock claudication. It is hypothesized that embolisation within the IIA disturbs collateralisation, resulting in persisting ischaemia, which is more symptomatic in the more active, less comorbid patient. Whether this may be attenuated by very proximal placement of embolisation coils in the IIA is not ascertainable from the data, though others have noted reduced complications with coil deployment into the main IIA trunk compared to more distally.[11] These data support a policy of selective IIA embolisation when deployment into the external iliac artery is necessitated.

Methods of IIA Preservation Following EVAR

Hybrid open and endovascular procedures

Early stratagems for IIA preservation relied on a combined open surgery and endovascular approach. Relocation of the IIA origin was first proposed by Parodi and Ferreira.[16] This technique entails deployment of a bifurcated endograft into the external iliac artery (EIA), thereby covering the IIA ostium (Fig. 1a). The IIA is isolated, ligated proximally to prevent backflow into the iliac aneurysm and a bridging graft sutured from the common femoral or EIA to the IIA remnant. This technique is disadvantaged by the need for significant retroperitoneal exposure and risk of venous, ureteric and collateral vessel injury. Though effective in preserving flow, IIA repositioning detracts from the minimally invasive nature of EVAR with a potential increase in morbidity and recovery time.

The Reverse-U stent graft described by Kotsis et al.[17] is another, more complex, stratagem for maintaining IIA

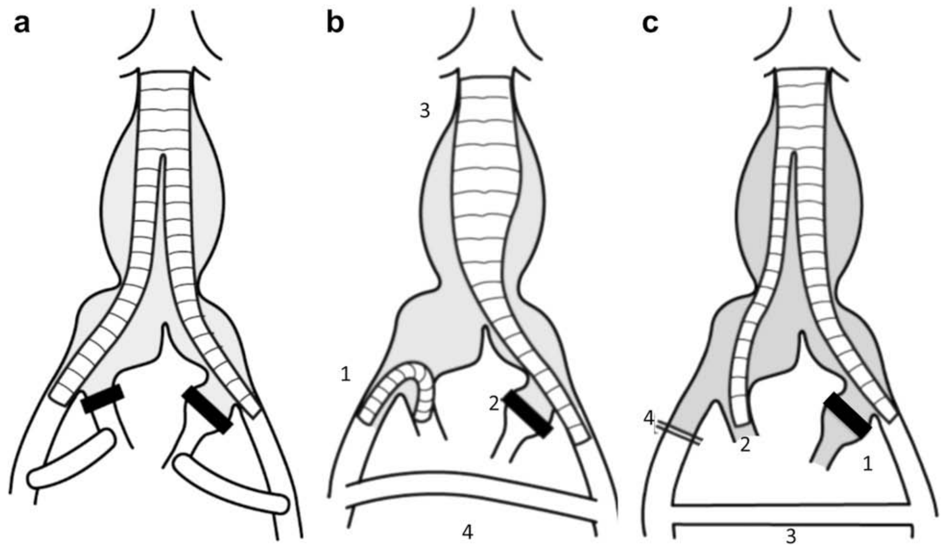

Figure 1 (a) Relocation of origin of internal iliac arteries. (b) The Reverse-U stent graft: (1) Stent from EIA to IAA; (2) Embolisation of contralateral IIA; (3) Aorto-uniiliac stent graft; (4) Femoro-femoral crossover graft. (c) Bifurcated stent graft: (1) Embolisation of ipsilateral IIA; (2) bifurcated stent graft with extension into ipsilateral EIA and contralateral IIA; (3) Femoro-femoral crossover graft and; (4) ligation of contralateral EIA.

perfusion (Fig. 1b). This technique entails deployment of an aorto-uniiliac stent graft after initial IIA embolisation, to exclude the aorto-iliac aneurysm. A contralateral EIA to IIA stent graft is deployed and flow to the contralateral limb is restored using a femoro-femoral crossover graft. Similar methods had been described prior to this report to manage iliac aneurysms. Hoffer et al. first described use of a specially modified covered EIA to IIA stent to exclude a common iliac artery aneurysm.[18] This was followed a year later by Derom et al., who used a Haemobahn™ endograft (W.L. Gore & associates) as an 'off-the-shelf' EIA to IIA conduit to repair a bilateral common iliac aneurysm after an open aortic aneurysm repair.[19] Clarke et al. used a Wallgraft™ (Boston Scientific) to same effect.[20] The EIA to IIA shunt allows pelvic perfusion through retrograde flow from the femoro-femoral graft. Drawbacks of this technique are the prolonged operating, contrast and X-ray times, and the reliance on retrograde flow to the contralateral leg and pelvis.

Another hybrid open/endovascular procedure described is by Delle et al.[21] Following embolisation of the ipsilateral IIA, an Excluder™ (W.L. Gore & associates) endograft main body deployed in the EIA via the femoral route. Through a brachial approach, the patent contralateral IIA is cannulated. A covered stent graft is then deployed into the patent IIA to exclude the aneurysm sac (Fig. 1c). The now unperfused EIA is then ligated to avert backflow into the aneurysm sac, and a femoro-femoral crossover graft fashioned to restore flow down both legs. Though perfusion to the IIA is more anatomic, flowing in an antegrade rather than

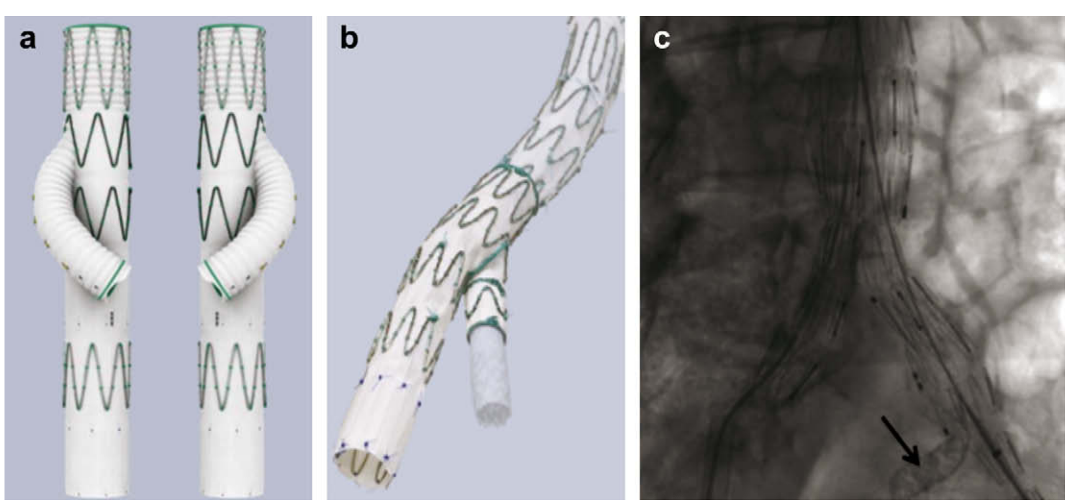

Figure 2 (a) Helical Branch Device. (b): ZBIS Device (Images courtesy of Cook Medical, UK). (c): Fully deployed ZBIS enhanced EVAR (Arrow highlights iliac side branch).

retrograde manner, this procedure is constrained in a similar manner to the Reverse-U graft. For both techniques, significant concerns exist with reference to the dependency upon the aorto-uniiliac graft and femoro-femoral cross-over graft as conduits for pelvic and lower limb perfusion; thrombotic or infective complications of either component would lead to devastating consequences for the patient.

Endovascular methods

Hybrid open and endovascular techniques to preserve IIA perfusion diminish the advantages bestowed by the minimally invasive nature of EVAR. A 'bell-bottomed' configuration to EVAR iliac extension limbs have been proposed to allow aneurysm sac exclusion in the presence of challenging iliac anatomy without recourse to open surgery. Though such endograft extensions have enjoyed success in some aneurysm morphologies,[22] the maximal 24 mm diameter confines their use to small iliac aneurysms or ectasia. More recently, iliac branch devices (IBDs) have been utilised as a purely endovascular solution to preserving IIA flow.

Iliac branch devices

An IBD is an endograft iliac extension limb that is characterised by a short side branch that is used to perfuse the IIA. The IBD is deployed in conjunction with the main body of an aortic stent graft to exclude the aorto-iliac aneurysm. IBDs preserve IIA perfusion, whilst preserving the benefits of minimally invasive endoluminal surgery.

IBDs have evolved over the last decade, which has seen this concept being integrated into single body[23] and modular[24,25] configurations. Success of early designs was constrained by stent graft dislocation or kinking, leading to thrombosis and endoleaks at the junction of the side branch and bridging stent graft. Contemporary IBD configurations derive from the design of Chuter and colleagues,[25] who constructed a bifurcated iliac component by amputating the proximal two stents from a Cook Zenith™ AAA endograft main body. Presently there are two IBD designs in usage; these are the Helical Branch Endograft (HBE) and the Zenith Bifurcated Iliac Side (ZBIS) branch devices (Fig. 2a and b). Over a thousand of such devices have now been deployed (personal communication Cook Medical UK) and both are based upon the Cook Zenith platform and used in conjunction with a standard Zenith Flex™ main body. The HBE (Fig. 2a) designed by Greenberg and colleagues consists of a 12 mm stent graft that extends from the origin of the common iliac artery to the EIA to which an 8 mm tubular branch is anastomosed in a beveled manner. The internal iliac branch length is 29.3 mm in length and runs longitudinally and circumferentially around the 12 mm tubular graft, terminating 150 degrees away from the proximal anastomosis. The device is configured with a left- or right-hand orientations and the long side branch length maximizes overlap with the bridging stent into the IIA. Unlike the ZBIS, the HBE is of a fixed length and sizing is not required. The HBE design aims to maintain rotational ability and to be capable of addressing angulation between the external and internal iliac artery origins in large common iliac artery aneurysms.

The ZBIS (Fig. 2b, c) resembles a standard Zenith limb extension but has a side branch attached to its body approximately half way down. To accommodate an IBD the target common iliac artery must have a diameter of at least 20 mm. The stiff ZBIS side branch is designed to facilitate IIA cannulation and protect against collapse and kinking which would result in side branch occlusion. In the USA the ZBIS and HBE devices have approval for investigational use only. Both ZBIS and HBE devices are recipients of a CE mark for marketing within the European Union. Further detailed descriptions of these devices are available elsewhere.[26,27] The price differential between IBD and conventional EVAR using the Zenith™ platform is £3000 (approx. $6000; personal communication Cook Medical, UK) plus the additional cost of the bridging stent. This should be taken into context with the overall pricing of EVAR compared to open surgery,[28] when economic issues are under consideration.

Accurate planning for an IBD enhanced EVAR necessitates high-resolution CT imaging with a maximum of 3 mm slices and 3 planar reconstructions. It is recommended that the target CIA should have a length of at least 50 mm and minimal diameter of 20 mm adjacent to the branch, In addition to these considerations, a wide aortic bifurcation, minimal IIA tortuosity and a long IIA landing zone are favorable anatomic factors. Twenty-French femoral access should be available but the operator should also be

Table 1 IBD series patient and operative details

Authors	No of centres	No of patients	Device used	Median Follow up (range) months
Dias et al.[32]	2	23	2 in-house 18 ZBIS 3 HBE	20 (8–31)
Ziegler et al.[29]	1	46	26 1st generation 20 ZBIS	24 (3–60)
Serracino-Inglott et al.[26]	1	8	ZBIS	6 (1–14)
Haulon et al.[31]	6	52	Helical	14 (–)

	Age	Median AAA diameter (mm)	Mean CIAA diameter (mm)	Median Op time (min)	Iodine usage (g)	Median Inpatient stay (d)
Dias et al.	70 (65–79)	52 (37–60)	34 (27–41)	279 (234–327)	58 (48–78)	4 (3–6)
Ziegler et al.	68.6 (52–86)	57.1 ± 11.2	32.3 ± 10.1	183 (100–330)	88 (35–180)	4 (2–44)
Serracino-Inglott et al.	72.1 (64–80)	48 (20–60)	31.5 (1.5–6.3)	101 (84–130)	101 (84–130)	4 (3–5)
Haulon et al.	72 (56–86)	56 (32–89)	38 (23–78)	–	208	–

Table 2 Indications for surgery in individual IBD series (by percent)

	Secondary procedure	AAA + CIAAA	Solitary CIAA	IIIA
Dias et al.	4.3	60.7	35	
Ziegler et al.	8.7	73.9	17.4	
Serracino-Inglott et al.	12.5	75		12.5
Haulon et al.		80	20	

(UICAA = unilateral common iliac aneurysm; BCIAA = bilateral common iliac aneurysm; IIIA = internal iliac artery aneurysm).

prepared to establish endovascular access from above. Excessive vessel tortuosity may compromise flow beyond the iliac bifurcation and make IBD delivery, orientation, rotation and cannulation difficult.

Evidence for IBDs

To date there have been three published single-centre[26,27,29] and two multi-centre[30–32] series for IBD usage. Since the Greenberg/Haulon[27,31] and Malina/Dias[30,32] series have short and medium term follow up data for the same populations published in separate papers, only the most recent data from each centre are considered for the purpose of this review.

The particulars of each series including aneurysm morphology, operative details and indications for EVAR are summarised in Tables 1 and 2. Taken together these series embody a total 129 patients. Haulon et al.[31], in the largest series, employed the Helical device. Dias et al.[32] primarily used the ZBIS in 18 cases, the HBE in 3 and in two cases an 'in-house' custom made endograft based on the Chuter design. Ziegler et al.[29] in a series of 46 used a now discontinued unibody design IBD for their first 26 patients, followed by the modular ZBIS in the final 20. Serracino-Inglott et al.[26] used the ZBIS in all eight patients. Aneurysm morphology in the Haulon et al. series is not fully elucidated, although 80% had bilateral common iliac artery aneurysm, 7.7% had iliac aneurysms with aortic diameters <5 cm, and at least 4% had undergone previous aortic reconstruction. In this series, it is noteworthy that 33% had the IBD deployed in conjunction with a fenestrated or branched main body.

Outcomes for individual series and pooled data are summarised in Tables 3 and 4. In all series, there were no instances of post procedure buttock/thigh claudication or pelvic/hindgut ischaemia in the presence of a patent IBD. The Haulon series does not elaborate upon total operating time, although mean fluoroscopy time was 64 min. Adjusting for the Haulon series, the mean overall operative time was 187 min. Intraoperative deployment failure occurred in 16.3% of cases, although 11.3% were accounted for by first generation devices. In the Ziegler and Haulon series thrombolysis and angioplasty were used successfully to treat thrombosis. Inability to cannulate IIA was managed by coverage of the side branch by a limb extension. Within 30 days of surgery, 8.5% of cases were discovered to have endoleaks, predominantly type II, and 7% of side branches were occluded. After 30 days, a further 7.8% of side branches became occluded and another 1.5% developed type II endoleaks, and IIA aneurysm formation was seen in a single patient (0.8%). One patient in the Dias series was found to have a type III endoleak at the junction of the IBD and main aortic endograft which was treated using an extension cuff. Overall mortality was 7%, with no aneurysm related deaths. The majority of deaths were reported in the series by Haulon et al., in which a third of patients had the IBD deployed in conjunction with a fenestrated main body endograft. Though such procedures are technically more challenging than conventional EVAR to a higher complication profile, it is not stated whether these patients were related with the reported mortality. Not included in this review is a more recent two patient case series reporting the successful treatment of common iliac artery aneurysms using IBDs following previous open infrarenal aortic aneurysm repair.[33] Neither patient had evidence of endoleak nor occlusion at ten-month follow up, although it

Table 3 Outcomes of individual IBD series

	Dias et al.	Haulon et al.	Ziegler et al.	Serracino-Inglott et al.
n	23	52	46	8
Intra-op	2 failures: 2 branch occl^n (1 ZBIS, 1 HBE)	3 failures: 2 unable to visualise IIA 1 unable to cross aortic bifurcation	16 failures (13 1st generation device): 2 device 8 cannulation 1 side branch deployment failure 5 intraoperative occl^n	0
30 day	1 Death (MI) 1 TIA 1 branch occl^n	6 IIA occl^n 2 EIA thrombosis 11 type 2 endoleak	0	1 IIA occl^n
Late	1 Death (MI) 1 Type 3 endoleak 3 branch occl^n	1 type 2 endoleak	4 branch occl^n	1 type 2 endoleak (IMA) 2 groin lymphoceles
Overall Mortality	2 (MI)	7 (6 MI, 1 intracerebral haemorrhage)	0	0

MI: Myocardial infarction; occl^n: occlusion; IMA: inferior mesenteric artery; TIA: transient ischaemic attack.

Table 4 Pooled outcome data from all IBD series

	n	(%)
Patients	129	
Optimum time (m)	187 (100—330)	
Median inpatient stay (d)	4 (2—44)	
Intraoperative failure	21	16.3
<30 d complications	10 IIA/EIA occlusions	7.7
	1 TIA	0.7
	11 Type 2 endoleak	8.5
>30 d complications	7 Occlusions	5.4
	3 Type 2 endoleak	2.3
	1 Type 3 endoleak	0.7
Mortality	9	7

is not indicated whether there were symptoms of pelvic ischaemia. Comparison between the published series highlights no clear advantages for either ZBIS or HBE device. As experience with these devices increases, the relative merits of each device in different aneurysm morphologies are likely to become elucidated.

Conclusion

The traditional endovascular treatment for aorto-iliac aneurysm entails IIA embolisation and landing the stent graft in the EIA. Contrary to popular perception, intentional unilateral IIA occlusion appears to carry a similar risk of symptoms as bilateral, ranging from 9—45%. However, the natural history of these sequelae remains unclear and there is a paucity of data defining the incidence of severe complications following bilateral compared to unilateral IIA occlusion. The role of hybrid open and endovascular techniques to maintain IIA patency can be questioned as they diminish the minimally invasive advantages of EVAR.

IBDs represent a significant advance in the endovascular management of aorto-iliac aneurysms. Deployment failures were predominantly issues with earlier generation devices, and with increased experience of contemporary IBDs we expect the incidence of intraoperative failures to further diminish. Long-term follow up data and larger series will further delineate the safety and efficacy of this device. It is the authors' practice to consider IBD enhanced EVAR as a first line treatment in selected patients, in whom the risks of symptomatic pelvic ischaemia would constitute a significant impairment to daily function.

Disclosure

Mr. Serracino-Inglott and Dr. Farquharson are European proctors for Cook Medical.

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